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Computer-supported collaborative learning and gender

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CHAPTER EIGHT

Conclusions and Discussion

8.1 Introduction

Computer-Supported Collaborative Learning (CSCL) is a promising tool in science education and is increasingly applied in school practice. Yet, CSCL carries a risk, particularly when gender is involved. Prinsen, Volman and Terwel (2007) have conducted a review study and indicated that gender problems that we are familiar with in the face-to-face collaborative setting still remain in CSCL environments. We find ourselves left with many questions. For example, whether female and male students differ in knowledge elaboration in CSCL and whether this is related to their learning achievement. So far, experimental studies focusing on the effect of gender in CSCL are rare. In order to gain an insight into the gender issue in CSCL, a series of empirical studies have been conducted. These studies arise out of three research questions:

- How do female and male students learn in a collaborative setting and do they both profit more from a collaborative setting than from an individual setting?
- Are there gender differences in collaboration with respect to students' communication style, cognitive representations and knowledge elaboration process?
- Is there a relationship between students' knowledge elaboration process and their learning outcomes in synchronous Computer-Supported Collaborative Learning (CSCL), and is this influenced by gender?

Study 1 and 2 were conducted to answer the first research question. Study 1 focused on whether collaborative learning is generally more effective for students than individual learning. The analyses of students learning achievement showed that collaborative learning improved students' solving of physics problems. Students in the collaborative condition scored higher than did students in the individual condition. Study 2 is indicative of a gender difference in collaborative learning.

In order to answer the second research question concerning students' interaction content during collaborative problem-solving, Study 3 and 4 were conducted. Study 3 sought to examine gender differences in communication styles while the purpose of Study 4 was to investigate the gender difference in cognitive representations during problem-solving.

From Study 5, the research swayed into a computer-supported learning environment. Study 5 is comprised of three case studies exploring a way to visualize the dyadic collaboration from a knowledge elaboration perspective. With the help of this visualization, a large study, Study 6, with 96 high school students was embarked, aiming at exploring the relationship between the gender differences in knowledge elaboration and students' learning achievement in CSCL.

This Chapter will begin with a brief account of each study. Next, an overview of the results will be presented, and the potentials of the research will be discussed. Finally, recommendations for future research and practical implementations will be presented.

8.2 Review of the Studies

8.2.1 Study 1: Collaborative Learning and Individual Learning (Chapter 2)

Solving problems doesn't only rely on the proficiency in recalling an equation or doing some symbol manipulation. Problem solving is at its best when students conduct a systematic analysis of problem information, make a synthesis of various problem solving methods, and critically reflect on the answer. However, students do not spontaneously generate highly elaborate explanations or questions on their own (King, 1990). Students tend to pay more attention to the literal aspects of the problem description and superficial application of equations or theorems. In the past twenty years, two heuristic methods, collaborative learning and individual learning with instructional help, have been widely adopted in classroom instruction. The value of collaborative learning is recognized due to the notion that while explaining a problem to a peer learner, students can gain conceptual clarity for themselves (Damon & Phelps, 1989; Johnson & Johnson, 1990; 1993). However, collaborative learning will be at risk of becoming conversational learning. Without the presence of tutors, students are inclined to chat and become less oriented towards their task. The aim of the first study was to find whether collaborative learning outperformed individual learning in enhancing students' learning performance. As a pilot study, it helped to fill out the pictures of collaborative and individual learning with hints.

The study was conducted in a secondary school in Shanghai with a sample of 99 students from two grade 11 classes. There were four experimental conditions: in Condition CL+H students collaborated with the help of hints; in Condition CL they collaborated without any hints; in Condition I+H students worked individually with the help of hints; in Condition I students worked individually without any hints. In total, there were 54 female students and 45 male students. The study was a randomized group design with a pre-test and a post-test. Students were randomly assigned to the four conditions. Students in the two collaboration conditions were randomly paired to work in dyads. Prior to the pre-test, we provided an introductory training to instruct the participants how to use the answer sheets. In the pretest, students were asked to solve two physics problems. After that they participated in six 50-minute experiment sessions. Both the pre- and posttest were one-hour long and students had to solve the problems individually, without any help.

Results

The analyses pronounced a significant difference of learning achievement between students in *Condition CL* and *Condition I*, and between those in *Condition CL+H* and *Condition I*. This indicated that collaborative learning was generally more effective than individual learning with hints for student's problem-solving learning.

It was also found that students in Condition I+H significantly outscored those in Condition I. But there was no significant difference between those in Condition CL+H and CL. The analysis showed that collaborative learning with hints was only slightly better than collaboration without hints. But a contrast test revealed that the difference between these two groups was not significant.

These results are congruent with previous research that has found collaborative learning excels individual learning with respect to the improvement of students' problem-solving achievement. Nevertheless, it was worth noting that female students seemed to profit less from collaborative learning than males. Study 2 grew out of the realization that there might exist a gender difference in learning achievement in the four conditions.

8.2.2 Study 2: Gender and Collaborative Learning (Chapter 3)

Collaborative learning is assumed to appeal to both male and female students (Heller & Lin, 1992; Johnson & Johnson, 1993; Kahle & Meece, 1994). However, some studies have clearly pronounced a notable gender difference in collaboration. For instance, females are more likely to hedge, qualify and justify their assertions (Fahy, 2003; Smith, McLaughlin, & Osborne, 1997). Even if a female student disagrees with her partner, she seems very reluctant to utter an emphatic "no". By contrast, males tend to assert their opinions strongly as facts (Blum, 1999; Fahy, 2002). Heller and Hollabaugh (1992) pointed out that female and male students may benefit differently from collaborative problem-solving. In contrast, Heller and Lin (1992) conducted a study concerning gender differences in university physics introductory education, and found that female students could perform equally well as male students when they were taught how to use an explicit problem-solving strategy in a collaborative learning environment. This raises the question, which method, collaborative learning or individual learning with hints, is better in closing the gender gap.

Study 2 arose from Study 1, using the same samples and database, but the research focus was narrowed to the gender difference in four conditions: Condition CL+H, CL, I+H and

I. The research aim was to find out know how collaborative learning and individual learning with instructional help operate in terms of how females and males learn differently.

Results

After the experiment, in condition CL and condition I there appeared to be a significant gender difference. In both conditions, male students excelled female students in the posttest. However, in Condition I+H, there was no significant difference between female and males' learning achievement. It seems that individual learning with hints may help to alleviate the gender gap in physics problem-solving in particular. In this condition, the females' answer sheets showed that they were actively involved in hint reading. Learning with the use of hints may make female students feel free to try and develop their own solving strategies.

In comparison with condition CL (collaborative learning without hints), it has been found that there was no significant difference between female and male students in condition CL+H. Having hints at hand may give the female students more confidence in developing their own problem solving strategies and arguing with their partners. Upon close examination of the students' answer sheets and the case study indicated that female students' problem-solving process may be influenced by their partner gender. The question is how partner gender influences students' learning process.

Thus, it was of great interest to explore whether female students' interaction and problem-solving process was sensitive to their partner's gender. Dillenbourg, Baker, Blaye, and O'Malley (1996) expressed the need to study the interactive processes that individuals and groups undergo during the collaborative learning. This triggered Study 3.

8.2.3 Study 3: Gender, Communicative Style and Problem Solving Episodes (Chapter 4)

Research indicates that females in single-gender collaboration outperform those in the mixed-gender collaboration (Siann & Macleod, 1986; Siann, Durndell, Macleod, & Glissov, 1988; Barbieri & Light, 1992). The presence of male students seems to make high-school female students reluctant to put forward their ideas and they become less active in collaboration. However, experimental studies focusing on female students' cognitive activities during collaboration and how this relates to their problem-solving achievement are sporadic (Hogan & Tudge, 1999). There is no clear empirical evidence whether female students' interaction style and problem-solving processes are influenced by their partner gender. Study 3 resorted to Bales' Interaction Process Analysis model (IPA) (1950, 1999) to look into students' communication style. The IPA model provides four categories for recording and analyzing the content and intensity of communication. The categories included twelve items indicating twelve types of behavior: a) Social-Emotional Area (positive): showing solidarity, tension release and agreement; b) Social-Emotional Area (negative): showing disagreement, tension and antagonism; c) Task Area (questions): asking for orientation, opinion and suggestions; and d) Task Area (answers): giving orientation, suggestions or opinions. In this study, some modifications were made to make the IPA model fit better into the problem-solving setting. The purpose of this study was to investigate whether partner gender influenced student's communication in collaborative learning in physics.

Fifty high school students (26 females and 24 males) in Shanghai, along with their physics teacher, participated in the study. Students were selected from two physics classes at grade eleven. Students were randomly paired with a peer learner from a different class. There were 12 mixed (*Condition MG*), 7 female-female (*Condition FF*), and 6 male-male dyads (*Condition MM*). The students in three conditions were exposed to the same number of experimental hours and the same instructional materials. The teacher first gave two introductory courses on Newtonian mechanics. Each took 45 minutes. One week before the experiment all students took a 50-minute pre-test to solve five problems individually. Then they were given a pre-flight training about how to use the communication log-sheets and answer sheets. The experiment consisted of four 45-minute long sessions. Each included two moderately structured problems. The data consists of students' pre- and post-test scores, and their written messages on the communication log-sheets. Students were asked to write down all the steps in the solution. Their written messages were analyzed with the modified Bales' IPA model.

<u>*Results*</u>

Analysis of students' pre- and posttest performances showed that female students' learning achievement was sensitive to their partner gender. Those working with a female partner excelled those collaborating with a male student. Students' written messages were also collected and analyzed. Of all 1,113 written messages generated by students in the four groups, 1,014 were identified as on-task interaction. Of the 1,014 on-task statements, almost all (999) could be categorized. There was a statistically significant difference in the number of messages across conditions. Females in *MG* were more likely to ask for suggestions and opinions. But they offered significantly less problem information, or suggestions about how to solve the problem. For male students more tension was found in *Condition MM* than in *Condition MG*. No significant differences were found in the other categories.

Study 3 on students' communication style only provided us with a surface understanding of what happened in collaboration. In order to solve a physics problem, students need to cognitively process problem information. The need for an insight into students' cognitive knowledge elaboration is obvious, such as how they make a qualitative analysis of variables, recall the relevant equations or laws, and map the relationships and substitute the numbers for calculation. We were more interested to know how they processed the knowledge cognitively and whether there existed a gender difference. Thus, we conducted our fourth study.

8.2.4 Study 4: Gender, Cognitive Representations in Collaborative Learning (Chapter 5)

Solving problems in physics involves far more than substituting the equations with numbers and manipulating them. Because representing information and high level cognitive processing of information are closely intertwined in problem solving in science (Kozma & Russel, 1997; Toth, Sunthers & Lesgold, 2002), we can make inferences to student's external representations produced in the interactions of problem solving to gain insight into his/her cognitive elaborations (DeWindt-King & Goldin, 2003).

External representation in physics problem solving refers to the configuration of formulating, illustrating, symbolizing, describing or paraphrasing problem components and information with tables, maps, charts or students' own words. For collaborative problem solving in physics there are normally two types of elaborative activities that students are engaged in: constructing a graph to illustrate variables or the problem solving strategy (visual representation), and verbally exchange of problem information (verbal representation). Visualization is recognized as a powerful step for successful problem solving (van Garderen & Montague, 2003). The visual representations of experts include not only declarative knowledge about the problem domain, but also strategic knowledge. For successful problem solving, high level vocabulary is necessary to describe a problem solution and to convey problem information in a scientific manner (Anderson, 1995). In collaborative learning, students are expected to engage in a deep intellectual level of interaction rather than fix on superficial talk, such as simply paraphrasing the problem information. We are interested to investigate whether there was a gender difference in knowledge representations in collaborative problem-solving and whether students' representation modes were sensitive to their partner gender.

This study rose from Study 3, using the same samples and database. We re-analyzed and categorized students' visual and verbal messages in interactions.

Results

The purpose of this study was to explore whether students' cognitive representations in physics collaborative learning varied across gender, and whether this was affected by their partner's gender. The analysis of students' verbal and visual representations on the communication log sheets suggested that female and male students did have different ways to represent knowledge. Female students preferred using verbal representations to convey problem information while males were more adept at visualizing problem components and mapping the problem solving strategies. But it was found that neither female nor male students' representation modes were affected by their partner's gender. It can be extrapolated that there may not be a great problem for single-gender collaborative problem solving because both interlocutors tend to use the same representational way to discuss the problem information and work out a solution. However, the finding got us reflecting on mixed-gender collaboration. What kind of problems may appear when female and male students work on a physics problem together but use different ways to represent the problem variables and the relationships between problem components?

From Study 1 to Study 4, we looked at a computer-alike collaborative learning setting because we thought that the computer itself might influence students' interaction. Having assessed gender differences in students' communication and cognitive elaboration, it was of interest to look into students' knowledge elaboration process during collaboration. Hmelo-Silver (2003) pointed out that understanding collaborative learning requires making sense of the interactions that students engage in and the tools that mediate their knowledge elaboration. Process-oriented studies into interactions are necessary to capture the situational dynamics of collaborative learning (Arvaja, Salovaara, Hakkinnen, and Jarvela, 2007). The study was shifted into a computer-supported collaborative learning environment. A case study, Study 5, was conducted, aiming at exploring a new method to visualize students' knowledge elaboration in CSCL.

8.2.5 Study 5: Visualizing the Knowledge Elaboration Process in CSCL (Chapter 6)

In collaborative learning, group is the learning agent (Suthers, 2006). The problem solving process can be regarded as a joint process of knowledge elaboration, which is made up of numerous meaningful artifacts, such as utterances, visual representations, gestures, and facial expressions in face-to-face collaboration. Joint knowledge elaboration is a process within which all participants should contribute to knowledge elaboration verbally and propositionally (Van Boxtel, 2000). CSCL that supports the exchange of visual and verbal representations can make students' ideas visible and preserve them in a shared context. Nevertheless, lack of co-present cues and a large amount of *incoherent communication* in synchronous CSCL may influence students' knowledge elaboration process. The aim of this case study was to find a possibility to visualize students' cognitive elaboration process in CSCL.

The computer program "PhysHint" was designed to foster students' online interaction. Six tenth graders (three females and three males) from a Dutch secondary school (VWO) participated in the five-day experiment. The research was limited to three dyads: a mixed-gender, a female-female, and a male-male dyad. The dyads were assigned to different periods of the day. Prior to the experiment, each dyad was given a twenty-minute pre-flight training and a sample problem about how to use PhysHint. Each participant was provided with a desktop computer with internet connection. In the experiment individual students were spread over different rooms to avoid talk. During the experiment session, the dyads were required to solve one or two moderately-structured physics problems within one hour and a half. The whole experiment was overseen by the researchers.

The server computer documented all students' online interactions. Sequential analysis which acknowledges that the message is a function of its context, was applied to look into these interactions. Each message was described as an elaboration to the problem solving. The content of each message was analyzed and endowed with a number, -1, 0 and +1. This was roughly in line with Kumpulainen and Mutanen's (1999) three cognitive processing modes. The initial state of students' knowledge elaboration was defined as 0. Each subsequent message was numbered according to its relation to prior sequence and the contribution to the solution. Off-task talk was coded as minus one (-1) because it ran the risk of directing the collaboration into non-sense talk. If it was a task-related message but didn't push the solving process, it would be coded as zero (0). This served to distinguish the superficial and elaborative talk in collaboration. When the messages were pertinent to the task of problem solving and contributive to the final solution, it would be coded as one (+1). Then we aggregated numbers of messages for each individual student, and plotted them sequentially to trace each individual's elaboration process in CSCL. For each dyad, there were two plotted curves representing the knowledge elaboration of each participant in the dyad.

Results

In the case studies, students' knowledge elaboration processeswere visualized and were presented in three patterns:

Cross Knowledge Elaboration: Students' knowledge elaboration curves looked more like two crossed curves. It is hard to find a salient individual difference in knowledge elaboration although at different periods of the problem solving process the collaboration was distributed. Both of the participants pushed the process of problem solving and knowledge elaboration.

Parallel Knowledge Elaboration: The knowledge elaboration curves kept almost parallel. The collaborative problem solving and knowledge elaboration process is jointly propelled while one was the asker and the other was the answerer.

Divergent Knowledge Elaboration: In the divergent pattern, students' elaborations were first closely entangled, but then diverged and the gap between them was getting larger and larger. One seemed to achieve a higher elaboration level than the other. In the case analysis, it was found that although this dyad generated the most on-task messages, one price paid for this was one student's relevantly low-level individual elaboration. Consequently, it was of great interest to find out whether the elaboration pattern is related with students' learning performance, and whether there exists a gender difference in knowledge elaboration.

8.2.6 Study 6: Gender, Knowledge Elaboration and Learning Achievement (Chapter 7)

CSCL research is explicitly founded on the claim that collaborative learning can improve individual learning achievement; the research methodology should be adequate for identifying these effects (Cress, 2008). Based on the knowledge gained in Study 5, Study 6 resorted to multilevel analysis to tackle the friction between the individual-level and the dyad-level. The aim of Study 6 was two-fold. First, it focused on the gender difference in learning performance and explored whether the single- and mixed-gender dyads presented different pictures of knowledge elaboration in CSCL. Second, it investigated whether students' gender, group gender, and knowledge elaboration process had an effect on students' learning achievement.

The study was conducted in a secondary school in Shanghai, China. Ninety-six students (49 females, 47 males) from two grade 10 classes participated in the two-week experiment. The average age of the students was 16. Students were administered a 40-minute paper-pencil pretest on Newton's second law. After that, they were given a 40-minute preflight training about how to use the online program "Physhint". The experiment lasted for two weeks, including six 40-minute long experiment sessions. Students were randomly paired to form 25 mixed-dyads, 12 female-female dyads and 11 male-male dyads. Within each experiment session, students were required to solve one moderately-structured physics problem concerning Newton's second law. Similar to former experiments, students were exposed to the same number of experimental hours and the same instructional materials.

Results

The analysis indicated that female students' learning performance was sensitive to their partner gender and the gender problems that we are familiar with in the face-to-face collaborative learning carry over into the CSCL setting. Based on the rationale that individual contributions as data points are interdependent and could be interpreted additively, we plotted the sums of the elaboration values along the timeline and found the patterns: divergent, cross and parallel. The study addressed a proportionally higher frequency of divergent patterns than cross or parallel patterns in the mixed-gender dyads than observed in the female-female and male-male dyads.

With respect to the question, whether females' relatively poorer performance in the mixed-gender dyads was correlated with the knowledge elaboration patterns, multilevel analysis was applied. It showed that in the mixed-gender dyads, the frequency of divergent patterns may explain the relatively low performance of female students on the posttest. The more divergent patterns, the lower females in the mixed-gender dyads score on the posttest. This finding potentially taps into a better understanding why female students performed worse in mixed-gender dyads than in single-gender dyads.

8.2.7 Summary and Discussion

As for the first research question, how female and male students learn in collaborative learning, it has been found that students learning collaboratively excelled those learning individually in general. This echoes previous research that has shown collaborative learning can generally improve students' learning achievement (Cohen, 1994; Johnson & Johnson, 1990, 1993; Scanlon, 2000; Slavin, 1983). During collaboration, students co-construct their knowledge through the interplays, and they can generate more abstract representations of the problem (Schwartz, 1995). However, the individual effect of collaborative learning may be masked by the overall attainment effect. Despite the benefits of collaborative learning, many researchers have pointed out the disadvantages of it such as the "free rider" effect (Kerr & Brunn, 1983) and the "sucker effect" (Kerr, 1983). It is widely known that simply grouping students does not ensure high learning achievement. Gender becomes one factor that both education researchers and practitioners cannot ignore. Howe, Tolmie, Anderson and Mackenzie (1992) have reported that there exist interaction failures for mixed-gender dyads in comparison with single-gender dyads working with physics problems. Mixed-gender dyads show lower levels of verbal interactions and slightly poorer performance than single-gender dyads.

In the first study, collaborative learning clearly produced a gender difference. Although there was no significant difference between female and male students on the pretest, male students tended to outscore female students on the posttest after a period of collaborative problem solving. Thus, it triggered a deeper investigation concerning how collaborative learning disadvantages female students in physics problem solving.

In order to know whether there exists a gender difference in students' communication styles, cognitive representations and knowledge elaboration processes in collaboration, I looked into the content of students' interaction. Students' interactions were classified according to Bales' IPA model, Schoenfeld's problem-solving episodes, and visual/verbal dichotomy. It has been found that females' communication style and their learning achievement were sensitive to their partner gender. Female students who were collaborating with male partners were more likely to hedge and ask for suggestions than females in single-gender dyads. Females put more effort on problem reading while males contributed more to calculations. Moreover, female and male students had different ways to represent knowledge. Females tended to use text-based messages in collaboration, while male students tended to use pictorial messages to illustrate problem information. Neither female nor male's representation ways were sensitive to their partner gender. Therefore, we may draw a temporary conclusion that there exists a qualitative difference between female and male students' communication styles and their ways to represent knowledge. However, knowing these is inadequate to unravel the complexities of collaborative learning. Individuals' thoughts, interpretations and actions are situational and evolve throughout the interaction

(Jarvela & Salovaara, 2004). The nature of the interaction between students influences their ongoing action and talks, thereby imposes an impact on their knowledge elaboration.

CSCL provided a rich context to investigate learners' interactions and knowledge elaboration process. But how to track the elaboration process sequentially is still a problem that researchers need to tackle. In order to find how students' elaboration process can explain their learning achievement and whether it is affected by students' gender, the "*elaboration value*" method was applied to capture the dynamics of the elaboration process during collaboration. With the help of this, three patterns of knowledge elaboration were defined: divergent, parallel and cross. Based on this methodological development, students' learning achievement could be correlated with their gender and elaboration patterns in CSCL. It has been found that the mixed-gender dyads generated proportionally the most divergent patterns. Besides, the more divergent patterns, the lower female students in the mixed-gender dyads scored on the posttest, while this was not the case for female students in single-gender dyads.

The close-up studies of students' communication styles, representation modes and synchronous CMC have revealed some factors resulting in the divergent patterns.

First, female and male students have different communication styles. Females in mixed-gender dyads ask for information or suggestions more often than their male partners. Accordingly, their male partners are more likely to provide help and offer advice. A great degree of uncertainty among female students can be found in the mixed-gender dyads. In contrast, females in single-gender dyads are not submissive and seem to be more confident in their abilities. Study 4 has shown that they put forward their ideas freely and are actively involved in problem solving.

Second, female and male students have different ways to represent knowledge. Female students are more likely to use words to delineate problem information while male students tend to use pictorial methods to visualize problem components and map the solution plan. Their knowledge representation ways will not change no matter if they work in a single-gender or a mixed-gender dyad. The discrepancy between female and male's communication and representation ways may become more obvious in synchronous CSCL in which physical cues are absent. For example, interaction break-downs have been frequently found in study 5 and 6. When the female student raises a question, it is very easily ignored by her male partner in synchronous CSCL. Instead of persevering in asking, studies on communication styles show that female students tend to be submissive and are more likely to seek consensus with their partner. The quick consensus building and the uncritical copying of knowledge from the partner have been found not indicative of an actual cognitive change, but is a coordinating discourse move (Fischer, et al., 2002; Weinberger, 2003). It may be detrimental to individual knowledge elaboration. Knowledge elaboration is at its best when students receive help and apply the help in the situation themselves (Webb, 1989). In addition, quiet, withdrawn passive behaviour will also prevent the engagement in the learning tasks.

The current studies suggest that gender plays an important role in both students' communication styles and cognitive representations. As for physics problem solving through CSCL, female students tend to be at a disadvantage. It may be due to the synchronicity of online collaboration that may impede females' knowledge elaboration when they are working with a male partner. Instant messaging generates numerous fragmented and incoherent interactions. Moreover, the lack of co-present cues and frequent breakdown of interactions are expected to reduce the effectiveness of collaborative learning.

These empirical studies swayed from the computer-alike face-to-face collaboration to a computer-mediated environment. Given the consideration that computer itself may influence students' communication and knowledge elaboration processes, the first four studies were conducted in a computer-alike collaborative learning setting. Students were randomly paired and asked to collaborate on the problems. They were not allowed to talk with each other. The communication between them only occurred on the communication log sheets. They could only use written messages to exchange ideas. Such kind of method facilitated an insight into students' interactions during collaboration and a focus on students' cognitive activities and communication styles. The data set included students' test scores, written interactions and computer-documented messages. The quantity of participation (to what extent learners contribute to discourse), has been regarded as an important indicator of knowledge construction (Barab & Duffy, 2000; Cohen & Lotan, 1995). Therefore, both students' text-based and visual representations were examined.

Most of the aforementioned studies have been conducted in line with a randomized experiment with pre-flight training, pretest, experiment session and posttest. Study 5 was based on three case studies. The selection of research methods relies on the specific research questions in each study. For instance, the first two studies (Chapter 2 and 3) concentrate on students' learning performance. Then, the quantitative method is applied. In contrast, the third and fourth studies (Chapter 4 and 5) focus on the interaction content of the students' collaboration. The qualitative analyses are used to look into students' communication messages. Study 5 (Chapter 6) explores a new method to visualize students' elaboration process. Thus, it uses the case studies to gain deeper insight into students' interactions. The last study aims at exploring the relationship between students' collaboration patterns and their learning performances, which is a synthesis of previous research results. Therefore, both quantitative and qualitative analyses have been applied.

Since the pre-flight trainings only concerned the use of the log sheets or the computer program, PhysHint, its impact on students' problem-solving practices has been minimized. Doing so guaranteed the validity of the experiment.

The studies were limited to dyadic collaboration due to the common sense that small group collaboration will result in more cognitive benefits and interactions not available to large group collaboration.

These studies were mainly conducted in Shanghai, China and only one case study was conducted in the Netherlands. It may be argued that there exists a cultural difference. As previously mentioned, the gender gap in physics is a global issue. Both in Europe, America and China, physics shows the largest gender gap with female students at a disadvantage. In addition, since this research focused on students' knowledge elaboration process, which shares a lot of traits among students across cultures, the influence of cultural differences seems to be minimal.

8.3 Recommendations for Future Research

The findings of these studies addressed a series of deeper questions and research interest. First of all, in the aforementioned studies, problem-solving strategies have been converted into hints and embedded into the collaborative settings. According to Schoenfeld (1994) one should not dictate strict problem-solving steps but give students room to develop their own problem solving strategy by asking them questions and giving hints. In study 2 (Chapter 3), it has been found that students learning with hints, either collaboratively or individually, outperformed those learning individually without hints, and there was no gender gap. It inspires the interest to know what kind of role the hints play in students' knowledge elaboration process. To put it in another way, it is of interest to investigate how the hints contribute to propel students' knowledge elaboration.

Second, the current studies were conducted in a synchronous CSCL environment. Asynchronous CSCL that allows students to learn at their own pace bears the opportunity to trigger more thoughtful discussions and critical thinking. Thus, it is of interest to study whether the asynchronous CSCL will excel synchronous CSCL in alleviating the gender gap in physics problem-solving learning. In order to answer this question, it is of significance to have an insight into the nature of students' interaction in asynchronous CSCL and how the partner gender influences students' ongoing action and talk in this situation. It was also found that when anonymity was allowed, women contributed strong assertive remarks, even though they did not engage in heated debates in face-to-face classrooms (Bellman, Tindimubona, & Arias, 1993).

Third, although we believe that the gender difference in physics learning is a global problem and the cultural may play an important role in the research of collaborative learning. Furthermore, to date little attention has been paid to culture-related issues in CSCL, especially when gender is involved. Some may argue that Asian females may have different communication styles in comparison with western females in the course of collaborative problem-solving. Given this research interest, it is important to study, with regard to the gender difference in CSCL interaction, whether there is a cultural difference. A cross-cultural comparison in this regard may help to picture the gender differences in communication styles in CSCL research.

There are also some methodological recommendations for researchers in CSCL. First of all, in analyzing CSCL interaction data, it is necessary for researchers to develop a good understanding of the “teen lingo” that is frequently used in web-based communication. For example, students tended to use “u” to represent “you” to speed up their typing. Secondly, in order to test the problem-solving skills, the delayed posttest is favored. The knowledge students have acquired should be tested in a new problem setting to see whether there is transfer. Thirdly, CSCL data unavoidably consists of lots of off-task interaction. In order to improve the effectiveness of students’ collaboration, CSCL design should take the learning goal, sub-goals and the responses into consideration. For example, it is worth probing whether we should provide students with very detailed hints and worked-out example.

8.4 Practical Implications

Taking the gender difference into account, the findings of these studies shed light on current research on practical classroom instruction. Each study provided some practical suggestions for teachers who tend to use collaborative learning, either face-to-face or computer-supported.

First, although students may generally benefit from collaborative learning in comparison with individual learning, we need to plan carefully to avoid the male monopolization in discussion if we want to steer female students in physics problem-solving. Designing some instructional help for students’ problem-solving may give the female students more chances to develop their own strategies and thereby close the gender gap. It is advisable to encourage female students to offer suggestions and raise questions more actively when they are working with a male partner.

Moreover, due to the fact that female’s communication styles were sensitive to their partner gender, for the mixed-gender collaboration, teachers should encourage the female students to raise their questions, insist on their opinions and develop their own problem-solving strategies. As female and male students have different ways of representing knowledge, it is suggested that we may provide female students more pictorially compiled hints to help them better understand their male partner’s visual messages.

These studies indicated that females were at a disadvantage in mixed-gender collaboration and that this was related with their knowledge elaboration process. Therefore, it is advisable for the teachers to rotate female students across mixed-gender and single-gender collaboration.

Finally, due to the numerous incoherent and fragmented messages, CSCL designers should hammer out how to technically overcome this problem in instant messaging. It may also be useful to provide some preflight training to remind students to keep their messages as coherent as possible. This might be a way out to reduce the frequency of divergent patterns.

The major implication for the educational practitioner involves the importance of considering the gender issue in designing and applying CSCL in physics education.